A STUDY OF THIN FILM VACUUM DEPOSITED JUNCTIONS

Semiannual Status Report

on

NASA Grant NsG-340

Submitted by:

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Report No. EE-4012-108-67U

June 1967

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SECTION I
REPORT COVERAGE

This semiannual status report on NASA Grant NsG-340 covers the period from Dec[redacted] 5, 1966 [redacted] June 5, 1967.

SECTION II
INTRODUCTION

The long range goal of this research project has been the development of thin film devices for use in instrumentation applications. However the basic problems in thin film physics have required us to devote our prime effort to filling in the missing and necessary fundamental knowledge of electrical conduction in such films. To date six basic papers have been or are being published[1-6] in this area by our research group. The most recent papers are fundamental to the theory of conduction in polycrystalline films and are the subject of this report as the material for each of these papers was completed during this research period.

SECTION III
CURRENT RESEARCH

Consider a polycrystalline film as shown in Figure 1(a). If the film is sufficiently thin and deposited under carefully controlled conditions, the individual crystallites will usually extend completely across the thin dimension of the film. The approximate diameter of the crystallites, in the plane of the film, will depend upon the deposition techniques employed, substrate material, and substrate temperature. Poor deposition procedures or an attempt to make the film too thin will result in the appearance of intercrystalline voids, as shown in Figure 1(b) and the film will be only partially continuous. For the purposes of this discussion we will assume that the film is completely continuous.

The net mobility may be written as

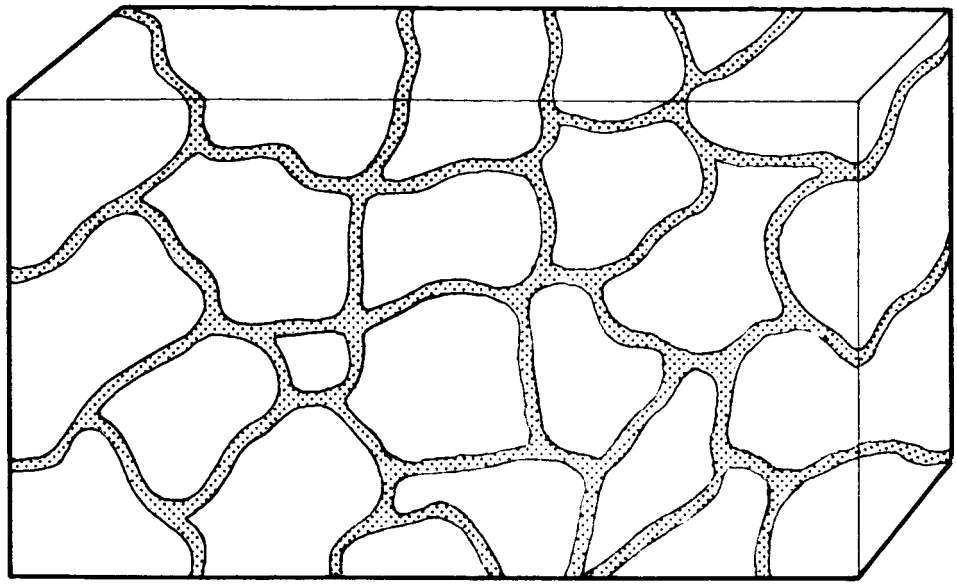
$$\mu = \left[\frac{1}{\mu_L} + \frac{1}{\mu_I} + \frac{1}{\mu_D} + \frac{1}{\mu_{LO}} + \frac{1}{\mu_{LP}} + \frac{1}{\mu_B} + \frac{1}{\mu_F}\right]^{-1} \qquad (1)$$

where μ_L represents the mobility of the charge carrier (electron or hole) as determined by the lattice (acoustic phonon mode) vibrations[7, 8], μ_I accounts for impurity scattering[9], and μ_D arises from scattering at dislocations[10]. In the case of compound semiconductors phonon scattering which is due to the optical mode vibration of the crystal lattice is important[11] and limits the overall mobility through μ_{LO}. If the semiconductor displays piezoelectric properties (II-VI compounds), then the net mobility is limited through μ_{LP}[12].

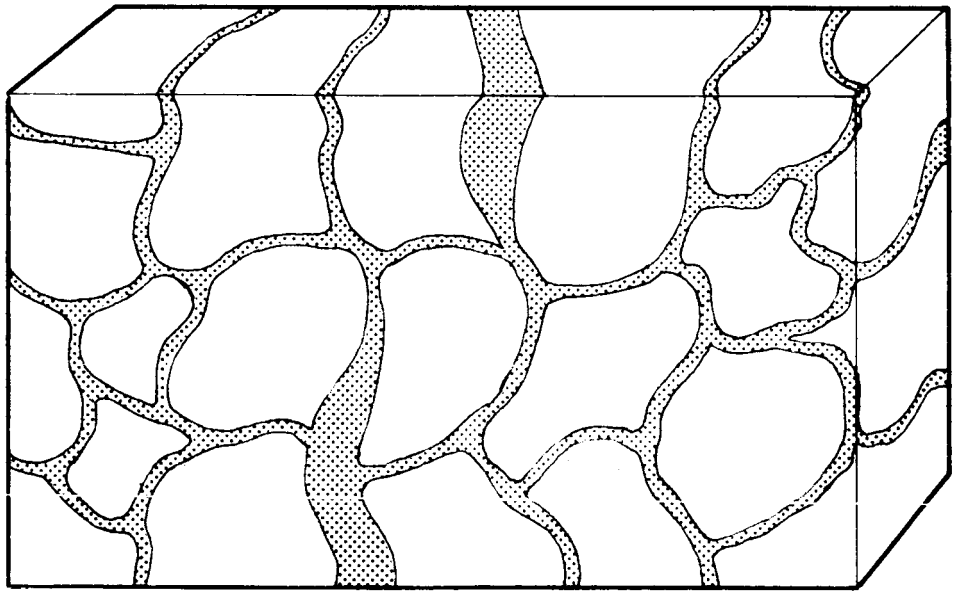
In addition to these terms, Petritz[13], has shown that scattering at the grain boundary is important in some compound semiconductors. The limitation on mobility because of the presence of intercrystallite barriers is

$$\mu_B = \mu_1 \epsilon^{-q\phi/kT} \qquad (2)$$

where ϕ is the barrier height. The coefficient μ_1 is usually a weak function of temperature.



(a)



(b)

FIGURE 1 (a) A typical polycrystalline film showing intercrystallite barriers and (b) a similar film showing partial discontinuities.

The final term accounts for the thin nature of the film and arises, in general, from surface scattering mechanisms. Although this term is probably present in all samples its presence is usually only detected when the thickness of the sample is on the order of or less than several mean-free-paths for the charge carrier. Ramey and McLennan[5] working under this NASA Grant have been able to show that the effect of film thickness can be accounted for by means of the mobility limiting expression

$$\mu_s = \mu_f \ell n \frac{\delta}{a} \tag{3}$$

where the coefficient, μ_f, is temperature independent and shows little variation with the crystal structure of the film for a given material. The film thickness is a, and δ may be termed the characteristic thickness of the film. It is highly dependent upon the structure of the film, having a value of 8,000 angstroms for polycrystalline germanium films (grain size about 1,000 angstroms) and dropping to about 2,000 angstroms for single crystal Ge films.

The last term, μ_F, is highly dependent upon the surface conditions and for single crystal films it should be possible to relate it directly to the surface mobility, μ_s, described by Schrieffer[14] and Green, Frankl, and Zemel[15]. The difficulties encountered in applying their theory make even computer aided solutions very cumbersome. Thus Equation (3) offers a more manageable approach for reducing experimental data.

For certain compound semiconductors such as indium antimonide (InSb) and cadmium selenide (CdSe), Equation (1) cannot satisfy the conductance vs. temperature characteristics. In such cases we have found that the effective mobility is better expressed by [6]

$$\mu = \mu_0 + \mu_1 \epsilon^{-q\phi/kT} \tag{4}$$

which is simply a combination of <u>two parallel conducting paths</u>. One, where the mobility is expressed by the second term (see Equation (2)), represents

conduction over barriers which separate the crystallites. And a second path, whose mobility μ_0 represents conduction <u>through</u> the barrier regions between the crystallites[16].

We have developed both Equations (3) and (4) during the course of our research under this grant. We hope to be able to further tie together the general theories of conductivity in polycrystalline materials during the final six months of this research effort.

SECTION IV
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